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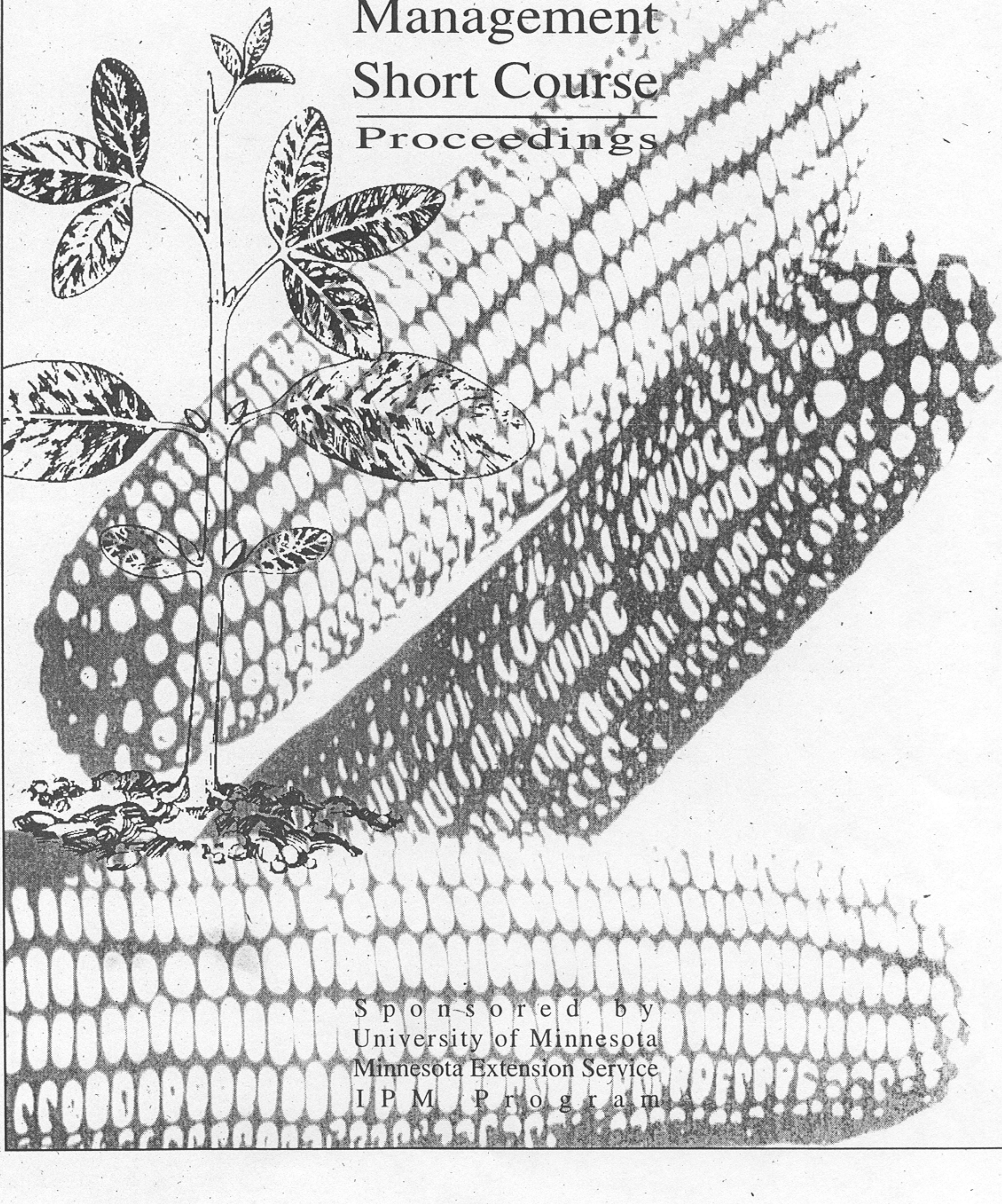

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Forecasting Weed Emergence and Growth: How and Why?

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Summary: Weed management decisions often can be more effective if the decision-maker has current knowledge of three weed variables: potential extent of seed germination, timing of seedling emergence, and postemergence rates of seedling development. In turn, such information helps the decision-maker determine three management variables, such as the necessity, type, and timing of weed control. Unfortunately, the three weed variables are difficult to predict because they are regulated by complex interactions among weather, soil, and management practices. Nevertheless, recent gains in our understanding of weed seed and seedling biology allow us to forecast the three weed variables at the times they are needed, that is on a daily basis in spring and early summer. We have synthesized, as much as possible, this new understanding of weed seed and seedling biology into an interactive Windows-based computer program called *WeedCast*. The intention of *WeedCast* is not to make management decisions. Instead, it is intended to provide crop consultants, producers, and agrichemical industry personnel with previously unobtainable biological information data aids them in making management decisions.

WeedCast

Version 1.0 (January 1997)

Forecasting weed seedling emergence and growth in crop environments

User's Manual

by

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Introduction and acknowledgements

Welcome to *WeedCast*, software that was developed to assist farmers, consultants, industry, and students to easily forecast seedling emergence and growth of common annual weeds of crops in the North Central region of the United States. This software is distributed as a fully self-contained, compiled, and executable program that was developed using Visual Basic™. Funding for the project came from the Agricultural Research Service (USDA-ARS) and from Minnesota's Agricultural Utilization Research Institute (AURI). The research and development process for *WeedCast* was conducted as a cooperative effort between USDA-ARS and the University of Minnesota. The information on weed biology needed to develop the program arose from published and unpublished databases provided by scientists from USDA-ARS and the State Agricultural Experiment Stations across the Corn Belt of the United States.

WeedCast predictions should be treated as guides or rules-of-thumb in situations where knowledge of weed biology is necessary for making weed management decisions. The predictions represent our best estimates based upon current understandings of the biology of the various weed species. *WeedCast* will be updated as regularly as possible to improve predictions. As well as add new weed species to its database. New versions of *WeedCast* will be released as a "downloadable" program through the homepage of the USDA-ARS North Central Soil Conservation Research Laboratory (http://www.mrsars.usda.gov/), and users should access this homepage regularly for updates.

Contents

1. Setting up

Installing *WeedCast* on your computer is accomplished by using the Setup program. The Setup program installs *WeedCast* in all the appropriate directories.

1.1 System requirements:

- IBm compatible machine with a 80386 processor or higher (486 or Pentium processors are highly recommended)
- Hard disk with a minimum of 8 megabytes available space
- 3.5 inch disk drive
- Windows 3.1
- Mouse or other suitable pointing device
- 4 megabytes of RAM

1.2 Setting up *WeedCast* from disks.

1. Insert Disk 1 into the 3.5 disk drive.
2. From Program Manager, choose File. Under File, choose Run.
3. In the Run command box, enter **a:\setup**.

This should successfully install *WeedCast* on the hard drive of your computer and create a *WeedCast* icon on your Windows menu.

1.3 Downloading *WeedCast* from the World Wide Web (after January 1997)

1. Access the homepage of the USDA-ARS North Central Soil Conservation Research Laboratory. The address is
http://www.mrsars.usda.gov/
2. Scroll through the homepage until you find "Current research," then "Weed research," and finally "Download Weed forecast model."

3. Follow the on-line instructions.

This should successfully install *WeedCast* on the hard drive of your computer and create a *WeedCast* icon on your Windows menu.

2. Program commands

Program commands are listed at the top of the *WeedCast* screen. These commands are as follows: <u>F</u>ile, <u>E</u>nvironment, Weed <u>F</u>orecasting, <u>W</u>indows, and <u>H</u>elp. The underlined letter in each of the program commands will allow the program to be implemented without a mouse. Selecting the 'Alt' key and the underscored letter will enable that command. However, we highly recommend that a mouse be used when running *WeedCast*.

2.1 File

The **File** title on the menu contains the following commands:

New
Open
Close
SaveAs
Print
Exit

2.1.1. File/New. Selecting **File/New** opens a blank spreadsheet for the user to enter weather data. The initial title of the spreadsheet is 'untitled'. This title has been reserved for use when opening a new spreadsheet. Therefore, before closing the spreadsheet, the user should choose **Save As** and select another name for the spreadsheet. A logical file name should be used. For example, if the closest weather station to your farm is Peoria, and you want to record weather data starting on May 1, 1997 (5-01-97), then a file name such as "Peo50197" might be easy to remember.

Files should start on logical dates, which depend upon the intentions of the user. For example, if you are interested in postemergence weed control, then you might want to start a weather data file on the day you planted your crop. On the other hand, if you are more inclined toward maximizing the effects of seedbed preparation as a form of weed control, then you ought to start the weather data file at a time well before anticipated weed seed germination, such as in early April for most annual weeds and sites in the Corn Belt.

2.1.2. File/Open. This feature displays an Open File box and allows the user to open a spreadsheet that already has been created or to open a graph that has been saved previously.

The spreadsheet can be opened and new data entered. If data are entered and the file is not save before closing, a message will appear prompting the user to save the file before closing.

Data to be entered include the following:
Day, Date, Minimum Temperature, Maximum Temperature, and Rainfall.

The Day should be numbered starting with zero (0). This is the first day in the spring that the user starts keeping weather data to use in forecasting weed seedling growth. Numbering starting with 0 will conform to the eventual graphs that are produced by *WeedCast*, all of which start with 0. Also, Day number should remain in strict count. For example, skipping from Day 15 to Day 17 in successive column rows may cause the graphing functions to be off slightly.

Date should be entered as the first date that weather data is kept. This can be any chosen day. For example, one file may start with April 15th as Day 0, whereas another file may start with March 20th as Day 0. The Day and Date column are used to keep track of the weather data over the course of a spring planting season.
Minimum and maximum temperatures and rainfall should be entered according to the observed or forecasted daily minimum and maximum air tempertures and rainfall. The values should be entered in English units; that is degrees Fahrenheit for temperature and inches for rainfall. (Apologies are extended to our international colleagues for the use of English units.)

If a graph is chosen to be opened, the graph will be for viewing purposes only. No further manipulation of the graph can be made. Further graphing of data must be done under **WeedForecast** menu title.

2.1.3. File/Close. Slecting **File/Close** closes the current file whether it is a graph file or a spreadsheet file. A message prompting the user to save the spreadsheet or graph is displayed if the currently active item has not been saved.

2.1.4. File/SaveAs. This feature allows the user to save the currently active graph or spreadsheet. Graph files must be saved with the '**.bmp**' extension and spreadsheet file must be saved with '**.ss**' extension.

2.1.5. File/Print. This selection will print the designated spreadsheet or graph to the designated active printer of the computer.

2.1.6. File/Exit. Selecting **File/Exit** will close *WeedCast* and return the user to the Windows screen.

2.2 Environment

The **Environment** menu allows the user to select the environmental conditions with which the weed forecasts will be completed. The following list boxes are shown on the **Environment** window:

2.2.1. Soil Type. Soil types to be selected are Sand, Sandy-Loam, Loam, Silt-Loam, Silty-Clay, Clay-Loam, and Clay. Choose the soil type that best matches the surface soil of the field in which you are interested.

2.2.2. Water Capacity. In this text box, enter the water capacity of the upper two inches of soil for the first day in the weather data file. Values range from 0 to 22 for a clay soil, and 0 to 10 for a sandy soil. In most instances you will <u>not</u> know this value, but you may make guesses. If the soil is clay and is extremely dry, enter 0; if saturated, enter 22; if moist, enter 11. If you are hopelessly confused, enter "Default" and an estimated soil water capacity value will be entered automatically. The number will not be shown in the text box but will be used in the calculations.

2.2.3. Weed Species. The weed species box allows the user to select the weed of interest for which emergence potential, emergence timing, or growth forecasts are to be generated. Unfortunately, a lack of biological research data prohibits us from making the three kinds of forecasts for each weed species. Forecasts currently are possible for the following weeds:

Weed species	Emergence Potential	Emergence Timing	Sdlg. Growth
1. Green Foxtail	X	X	X
2. Giant Foxtail	X	X	X
3. Yellow Foxtail		X	X
4. Redroot Pigweed	X	X	X
5. Com. Lambsquarters	X	X	X
6. Wild Buckwheat	X		X
7. Pennlysvania Smartweed	X	X	X
8. Barnyardgrass		X	x
9. Proso Millet		X	x
10. Com. Sunflower			x
11. Black Nightshade		X	x
12. Com. Cocklebur		X	x
13. Kochia			X
14. Velvetleaf		X	x

We plan to lengthen and fill the gaps in this table as soon as pssible over the next few years. Users should inform us of important species that are missing from this table, so that we may give those species high priority in our forthcoming research.

2.2.4. Crop. The **Crop** list allows the user to enter the previous year's crop.

The choices for this are Corn, Soybean, or Other. Information on previous crop is used in making soil temperature conversions from air temperature.

2.2.5. Tillage system. The**Tillage** list allows the user to enter the type of tillage used in the previous year. These choices include Moldboard plow, Chisel-plow or No-till. Information on tillage system is used in conjunction with previous crop to make soil temperature conversions from air temperature.

All these selections must be made before the calculations can be run. If a selection is omitted, the graphing function under **WeedForecast** will stop the calculation and prompt the user to enter a selection.

2.3 WeedForecast

2.3.1. WeedForecast/Emergence Potential. Choosing this option will present the user with a screen that has a blank graph to the left, a frame with 4 blanks on the bottom, and 2 buttons, titled '**EmergPot**' and '**Graph**' in the bottom right corner.

Emergence potential, when calculated, forecasts the percent of weed seeds that may germinate and emerge under the current weather and environmental selections. Essentially, emergence potential is an index of the nondormant seedbank. Under optimum weather conditions emergence potential is high, but when certain weather events occur, dormancy may be induced and emergence potential decreases as a step function. If these dormancy-inducing events occur early, then the down-step is great, whereas if the dormancy-inducing weather event occurs late, the down-step is relatively shallow. Each weed species reacts differently to dormancy-inducing weather events.

To calculate and graph emergence potential, a weather data file with data must be saved and conditions selected under the **Environment** window. Once these selections have been made, the user may press the button, **EmergPot**. This button will run the calculations.

Once the calculations are complete, the user selects the **Graph** button. Subsequently, the graph will appear, while at the same time the variables for the graph will be written to the current weather data spreadsheet under the heading for the selected weed species. Also, the selections made on the **Environment** sheet will be written in the boxes in the frame at the bottom of the graph.

If the user neglected to enter appropriate environmental conditions or has not opened a weather data sheet, the calculations will be stopped and a message box will inform the user which variables are needed.

2.3.2. WeedForecast/Emergence Timing. Choosing this option will present the user with a screen that has a blank graph to the left, a frame with 4 blanks on the bottom, and 2 buttons, titled '**CalcEmerg**' and '**Graph**' in the bottom right corner.

Emergence timing, when calculated, forecasts the cumulative percent of weed seedlings that have emerged up until the last day of the weather file. Observed or forecasted weather data may be used for this last day, as well as any other time period. Essentially, emergence timing is an index ranging from 0 to 100 of relative weed emergence. That is, of the total number of weed seedlings that will eventually emerge this year, what percentage emerged as of today or any other selected date for which weather data exists. Under optimum weather conditions emergence timing proceeds rapidly, but when conditions are too cold and/or too dry, emergence may slow or even cease. Furthermore, after emegrence reaches relatively high values, a mathematical damping function (the logistic) curtails the rate of emergence regardless of weather conditions. This damping function simulates depletion of the nondormant seedbank through germination.

To calculate and graph emergence timing, a weather data file with data must be saved and the conditions selected under the **Environment** window. Once these selections have been made, the user may press the button, **CalcEmerg**. This button will run the calculations.

Once the calculations are complete, the user selects the **Graph** button. Subsequently, the graph will appear, while at the same time the variables for the graph will be written to the current weather data spreadsheet under the heading for the selected weed species. Also, the selections made on the **Environment** sheet will be written in the boxes in the frame at the bottom of the graph.

If the user neglected to enter appropriate environmental conditions or has not opened a weather data sheet, the calculations will be stopped and a message box will inform the user which variables are needed.

2.3.3. WeedForecast/Seedling Height. Choosing this option will present the user with a screen that has a blank graph to the left, a frame with 4 blanks on the bottom, and 2 buttons, titled '**CalcHeight**' and '**Graph**' in the bottom right corner.

Seedling height, when calculated, forecasts the cumulative height growth of the average emerged seedling of the selected speceis up until the last day of the weather file. Observed or forecasted weather data may be used for this last day, as well as any other time period. Seedling height is forecasted in the range of 0 to 10 inches. Equations used to calculate seedling height are not valid beyond the height of 10 inches.

To calculate and graph seedling height, a weather data file with data must be saved and the conditions selected under the **Environment** window. Once these selections have been made, the user may press the button, **CalcHeight**. This button will run the calculations.

Once the calculations are complete, the user selects the **Graph** button. Subsequently, the graph will appear, while at the same time the variables for the graph will be written to the current weather data spreadsheet under the heading for the selected weed species. Also, the selections made on the **Environment** sheet will be written in the boxes in the frame at the bottom of the graph.

If the user neglected to enter appropriate environmental conditions or has not opened a weather data sheet, the calculations will be stopped and a message box will inform the user which variables are needed.

2.4 Windows

At the time one or more graphs are displayed by *WeedCast*, two other windows will be open and overlain by the the graph. These other windows represent the weather data and environmental parameters. To display each of these windows simultaneously, select cascade, vertical, or horizontal in the **Windows** box.

2.4.1 Windows/Cascade. This displays each of the graphs sequentially and overlapping from the upper left of the screen to the lower right. Any one of these graphs can be brought to the forefront simply by using the mouse to point and click on any portion of the desired graph or other windows.

2.4.2 Windows/Vertical. This displays each of the graphs sequentially and overlapping from the top to the bottom of the screen. Any one of these graphs can be brought to the forefront simply by using the mouse to point and click on any portion of the desired graph.

2.4.3 Windows/Horizontal. This displays each of the graphs sequentially and overlapping from the left to the right of the screen. Any one of these graphs can be brought to the forefront simply by using the mouse to point and click on any portion of the desired graph.

Each window (graph, spreadsheet, or environment) can be sized by dragging the lower right corner of the window with the mouse's double-arrowed pointer.

2.5 Help

Users must recognize that *WeedCast* developers are not professional software programmers. Consequently, we were able to provide only limited on-line help. Furthermore, because the developers have many other duties, we can accept very limited numbers of calls for assistance. We trust that the simplicity of the model should reduce the need to call upon us for assistance. If you must call us, however, our telephone number is 320-589-3411 ext 127, and our e-mail address is fforcella@mail.mrsars.usda.gov.

3. Background biology and limitations

3.1. General comments and limitations. Development of *WeedCast* evolved over a number of years and after a number of inquiries by producers, crop consultants, and agri-chemical professionals regarding emergence and growth patterns of weed seedlings. During this time we had gathered substantial amounts of empirical information regarding these topics. However, we did not have a medium by which we could tranfer this information easily to potential users, except through channels of normal scientific publication. The concepts behind much of the *Weedcast* predictions have been published in these sources. Unfortunately, the only people who read such publications are other scientists, and even then, only few of them do so.

Consequently, we chose to package our voluminous databases and equations into a medium that permits hands-on interaction by the people who really need information on weed biology on a daily basis in spring and early summer. In the process of condensing this information and providing it in a user-friendly format, much of the variability and error, which normally are documented rigorously in standard scientific publications, are hidden from the user in *WeedCast*. Thus, the user must beware that the predictions offered by *WeedCast* may be affected by substantial error, although we hope this does not occur often. Nevertheless, all forecasts made by this program should be treated as rules-of-thumb and used as guides rather than as definitive answers to questions regarding the emergence and growth of weed seedlings.

3.2. Soil temperature. The driving force behind many of *WeedCast*'s predictions is soil tempertaure. Soil temperature is, perhaps, the most important ecological variable for soil-borne seeds and seedlings before they reach the soil surface. Consequently, *WeedCast* uses daily estimates of soil temperature to run the **Emergence Potential** and **Emergence Timing** routines.

Unfortunately, few people have access to daily estimates of soil temperature. A process was needed, therefore, to convert readily available air temperature measurements into soil temperatures. Fortunately, equations were published by Gupta et al. (1983) that provided a means to convert daily maximum and minimum air temperatures into soil temperatures for various soil types, tillage systems, and residue conditions. These conversions did not estimate soil temperatures perfectly, but we used them because they provided reasonable approximations, and they were relatively easy to program.

3.3. Soil water potential. The second driving force behind many of *WeedCast*'s predictions is soil water potential. This is an extremely difficult variable to measure directly in the field, not to mention estimate from simple microclimate observations. Soil physicists still argue about how to estimate soil water potential accurately, even with access to a wide variety of detailed hourly weather measurements.

To circumvent these difficulties for *WeedCast*, we used the crude but practical soil water potential model developed by Forcella (1993). This model estimates soil water potential of the top 2 inches (5 cm) of soil during spring based on soil temperature and rainfall. The model must be initialized with "soil type" so that parameters for water holding capacity, water retention, and bulk density can be chosen automatically. Additionally, initial soil water content requires specification so that the model can have an initial value with which to begin calculations.

3.4. Emergence potential. Seeds of many summer annual weeds are dormant at the time they are shed from their parental plants. Even older seeds in the soil seedbank may be in a state of dormancy at the end of summer. Sometime during the following autumn, winter, and/or early spring a proportion of these seeds become capable of germination. At this time they have maximum "emergence potential." Maximum emergence potentials of several species were reported by Forcella et al. (1997), and these are repeated here: giant foxtail 100%, velvetleaf 53.5%, kochia 50.2%, Pennsylvania smartweed 48.5%, common purslane 44.9%, common ragweed 38.2%, green foxtail 20.5%, wild proso millet 16.1%, hairy nightshade 9.3%, common sunflower 6.3%, yellow foxtail 5.6%, pigweed spp. 13.1%, common lambsquarters 10.1%, wild buckwheat 4.7%, and prostrate knotweed 1.1%.

Maximum emergence potential, however, is rarely realized by these species. Certain environmental conditions may occur in spring or early summer that induce what is known as "secondary dormancy" in some of these species. We do not yet know the conditions that induce secondary dormancy in most species susceptible to secondary dormancy. However, we have been able to estimate these conditions for some species based upon empirical relationships between the proportion of a seedbank that emerged over the course of an entire growing season and single-day events that occurred in spring or early summer (Forcella et al. 1997). These species were giant foxtail, green foxtail, Pennsylvania smartweed, wild buckwheat, common lambsquarters, and pigweed. *WeedCast* predicts decreases from maximum emergence potential for these six species based on daily weather events. Predictions for the remainder of the species await greater and more detailed research efforts.

3.5. Emergence timing. The time at which seedlings emerge in spring is predicted by *WeedCast*. These predictions are based upon two sets of equations, as outlined in Forcella (1993). The first set of equations describes the effects of soil tempertaure on the velocity at which non-dormant seeds germinate. The second set describes the effect of soil water potential on seed germination. Originally, these equations were developed for velvetleaf and were based upon data derived from extensive and intensive laboratory experiments. However, conducting such laboratory experiments for all species treated by *WeedCast* was not practical. Consequently, we required an alternative methods of quickly developing sets of emergence equations for a large number of species.

Timing of seedling emergence data were collected for several species over the course of five years at the Weed Nursery of the University of Minnesota's Rosemount Experiment Station. From these data "emergence curves" were constructed; i.e. cumulative relative seedling emergence plotted against calendar date. Similarly, emergence curves were constructed from data gathered by committee members of the NC-202 Regional Research Committee. These data came from 10 site-years from Ohio to Colorado, and Missouri to Minnesota (Forcella et al. 1997).

Using the velvetleaf emergence model as a template, coefficients for equations describing temperature and water potential effects on emergence were manipulated for each of 13 species. These new empirical models were then tested using site-specific daily soil temperature and rainfall data. Results from these models were then compared to the observed emergence curves. Coefficients were manipulated until a high level of agreement between predicted and observed emergence values were apparent. These empirically derived equations were then inserted into the *WeedCast* software.

3.6. **Seedling growth**. The pace at which seedlings increase in height up to about 10 inches (25 cm) is predicted by *WeedCast* based solely upon growing degree-days. Growing degree-days are estimated from air temperatures. Base temperatures used in calculating growing degree-days are either 40 F (4.4 C) or 50 F (10 C) depending upon species.

Empirically derived equations that describe growing degree-day effects on seedling height growth of giant, green, and yellow foxtail in field settings (Forcella & Banken 1996) were the templates used for all other species. Data for other species were derived from Dawson[1] (1963), Frazee & Stoller (1972), and especially from Wilson et al. (1992). Similarly, unpublished field studies at the University of Minnesota's West Central Experiment Station, and in the greenhouse of the USDA-ARS Soils Lab (Morris) provided additional data for calculating height growth of many different weed species.

Previous experiments indicated that soil water potential played only a small role in regulating seedling height growth up until about 10 inches (25 cm) height. We assume that if enough soil water existed for a seed to germinate, the resulting seedling had enough soil water to grow to about 10 inches. We recognize that this assumption lacks universal applicability, and users of *WeedCast* must also recognize this limitation.

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[1]We thank Dr. R.G. Evans, USDA-ARS, Prosser WA, for supplying the weather data that corresponded to the experiments performed by Jean Dawson during 1960.

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